STUDIES ON NUTRIENT ABSORPTION BY RICE PLANTS IN TAIWAN (PART 1)

Effect of Temperature on Nutrient Absorption by Rice Plants

by

T. F. CHIU, S. LIAN and S. C. HSU*

It is a general tendency of the yield of crops to increase in accordance with the increase of nutrient absorption. Since nutrient absorption is generally promoted under high temperature to a certain limit, yield should increase as the temperature gets higher. Takahashi (1952) reported that rice plants absorbed nutrients more in a high temperature condition than in a low temperature one, and considered that the nutrient absorption depends on the respiration of plant which in turn is influenced greatly by temperatures.

However, the grain yield of rice in the regions or in crop seasons under high temperatures is generally lower than under low temperatures. For instance, tropical countries generally give lower yield than temperate countries, and the yield of the second crop (July-October) in Taiwan is also less than that of the first crop (January-June) which is under lower temperatures.

It was suggested in this connection by Iso (1954) that in high temperature regions as in Taiwan, the growth of some Japonica rice varieties is promoted by intensive nutrient absorption, but flower initiation is advanced and the total yield might be reduced, because of a too short growing period. It has been also demonstrated that some Japonica varieties have relatively high fertilizer response under the high temperatures in Taiwan (Oka, 1956). However, those varieties are generally too early in maturity and their yield is low under the condition in Taiwan. Their earliness is due either to photoperiodic response or to their tendency to keenly respond to high temperatures so as to advance flower initiation. Owing to the rapid growth and prematurity, the total amount of nutrient absorbed might be reduced.

It is also commonly known in Japan that the straw/grain weight ratio of the yield of rice grown in warm climatic area is larger than that in cold climatic area (Togari, 1953). In the first and second crops of rice in Taiwan, the straw/grain weight ratio is noted as 110/100 and 120/100, respectively. Due to the rapid growth of rice under high temperatures, the nutrients absorbed may tend to be consumed for the formation of leaves and stems and for respiration, leaving little for the production of grains. Torii (1958) stated that the low yield in the second crop of rice in Taiwan, as compared with the first crop, is due to the reverse climatic conditions of the two crop

* Taiwan Agricultural Research Institute

seasons. Rice grows with rising temperatures in the first crop, while with declining temperatures in the second crop. This difference in temperature will strongly influence on the physiological activity of rice plants which in turn affect the response to fertilizer. He has shown some evidence for illustrating the cause and mechanism of high response of rice to potash under high temperatures.

However, the causes of low yield of rice in high temperature regions are still obscure in details. The authors are interested in the relation between climatic conditions and the growth of rice plants, and have taken up this study in order to throw some light on this problem from the view-point of nutrio-phisiology. Greenhouse experiments were conducted to clarify the actual status of nutrient absorption by rice plants under different temperatures, as reported in this paper.

METHOD AND MATERIAL OF EXPERIMENT

Pot experiments in glass-houses were conducted to investigate the effect of high and low temperatures on nutrient absorption and growth of rice plants.

1. Temperature treatment

Comparison was made between two glass-houses, one with closed windows and the other with opened windows.

2. Variety used

A Japonica rice variety, Taichung No. 65 was used. The soil for pot culture was taken from the experimental farm of this Institute. It is sandstone and shale alluvial soil, pH 5.5 and silt loam in texture.

3. Conditions of pot culture

Each of the pots was filled with 10 kgs of the above mentioned soil and was dressed with ammonium sulphate, calcium superphosphate, potassium sulphate at the rate of 1 gm of N, P_2O_5 and K_2O respectively, and 5 rice seedlings were planted inst. Five pot samples from each temperature treatment were taken five times at different growth stages as given in Table 1. 50 pots in total were thus observed.

Table 1. Sampling date (1st and 2nd crop, 1959)

	1st crop (days after planting)	2nd crop (days after planting)
Planting	March 26 (0 day)	Augugt 13 (0 day)
1st Sampling	April 28 (33 days)	September 8 (35 days)
2nd Sampling	May 15 (50 days)	October 1 (48 days)
3rd Sampling	June 1 (67 days)	October 21 (68 days)
4th Sampling	June 29 (95 days)	November 9 (87 days)
5th Sampling (harvest)	July 28 (124 days, Low temp. plot) August 8 (135 days, High temp. plot)	December 18 (126 days)

4. Recording of the growth of plant

Agronomic characters of rice plants, e. g. length of straw, number of culms etc. were investigated every week. Plant weight was also recorded at each sampling time, and the samples were divided into three parts after harvesting, i. e. stem, leaf and sheath, and grain providing for chemical assay.

5. Chemical analysis

Plant samples after air-drying were dried further in an electric oven at 85°C, and then were pulverized. Nitrogen content was determined by semi-micro Kjeldahl method. Micro-digestion of plant samples (Piper 1953) was adopted for phosphorus and potassium determinations. Molybdenum-blue method using hydrazin sulfate as reducing reagent was adopted for determination of phosphorus, and potassium was analyzed by flame photometric method.

RESULTS

1. Investigation of temperature

Room temperatures in the two glass-houses at 10 a. m. was recorded every day during the growing period. The former had always 2°~3°C higher than the latter as shown in Fig. 1. The average temperatures were as follows:

Table 2. Average room temparature at 10 a. m.

	1st crop (Mar. 26-Aug. 8)	2nd crop (Aug. 13-Dec. 18)
High temp. glass-house	30.9°C	29.8°C
Low temp. glass-house	27.9°C	27.0°C
Difference	3.0°C	2.8°C

2. Growth and yield of rice plants

Length of straw and tiller number measured at successive stages of growth are shown in Fig. 2. Plant weights at different stages are shown in Fig. 3.

Table 3. Measurements of agronomic characters at maturity

	1st crop		2nd crop	
	High temp.	Low temp.	High temp.	Low temp.
Length of straw (cm)	116.6	104.0	117.4	111.8
Number of tillers	26.6	26.2	26.4	26.8
Total yield (g/pot)	92.2	76.9	101.7	98.1
Grain (g/pot)	13.7	27.2	40.8	31.8
Straw (g/pot)	78.5	49.7	60.9	66.3
Grain/Straw	17/100	55/100	67/100	48/100

The high temperatures in the closed glass-house apparently promoted the elongation of straw, similarly in the 1st and 2nd crops. The date of heading in the high temperature plot was a little earlier than that in the low temperature plot. However, the number of tillers did not seem to be effected so much by the difference in temperature. The weights of plants in the high temperature plot, shown in Fig. 3, were larger, especially in the 1st crop, than that in the low temperature plot.

3. Inorganic nutrient absorption by rice plants

Table 4. Inorganic nutrient content of rice plants at successive growing stages (% on oven dry basis)

		High temp. plot				Low temp. plot		
		N%	P_2O_5%	K_2O%		N%	P_2O_5%	K_2O%
1st Crop	March 26 (planting)	1.14	0.868	1.56		1.14	0.868	1.56
	April 28	3.21	0.860	4.37		3.74	0.875	2.80
	May 15	4.21	0.808	4.56		4.41	0.890	2.35
	June 1	3.28	0.800	3.65		3.71	0.938	1.58
	June 29	1.79	0.657	1.94		1.55	0.701	0.91
	Aug. 8 (harvesting)	1.31	0.580	1.64	July 28	1.12	0.550	0.88
	Grain	1.32	0.615	0.64		1.32	0.611	0.62
	Stem	0.75	0.803	1.20		0.73	0.840	1.30
	Leaf	1.46	0.521	1.97		1.10	0.423	0.94
2nd Crop	Aug. 13 (planting)	2.86	0.958	3.65		2.86	0.958	3.65
	Sep. 8	3.64	0.985	4.94		3.74	0.943	5.04
	Oct. 1	3.50	0.938	44.2		3.18	0.825	3.65
	Oct. 21	2.20	0.782	3.50		2.28	0.792	2.98
	Nov. 9	1.45	0.660	2.52		1.52	0.644	2.09
	Dec. 18 (harvesting)	1.18	0.558	1.83		1.33	0.527	1.61
	Grain	1.40	0.702	0.65		1.58	0.698	0.67
	Stem	0.66	0.682	3.84		0.92	0.534	2.50
	Leaf	1.22	0.355	2.04		1.37	0.394	1.85

As shown in Table 4 and Fig. 4, the N, P_2O_5 and K_2O contents of the rice plants were increased gradually after transplanting. The plants showed the highest inorganic nutrient content at about 50 days after transplanting in the 1st crop and 25 days in the 2nd crop, then the nutrient contents made a slow dropping till harvesting time. It was found that the K_2O contents in the high temperature plot, especially in the 1st crop, were evidently higher than that in the low temperature plot. In the 1st crop, N and P_2O_5 contents of the plants before heading in the low temperature plot were a little higher than those in the high temperature plot, but in the latter stage, the order was reversed.

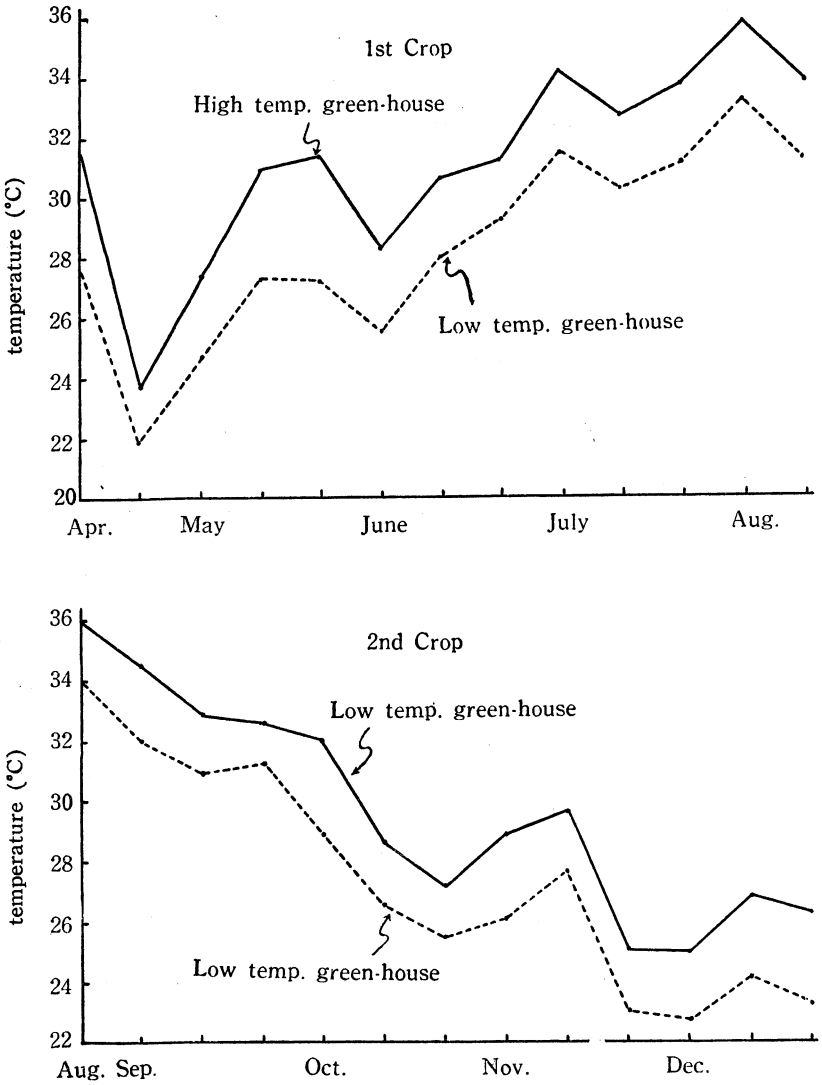

Fig 1. Change of temperatures in two glass-houses

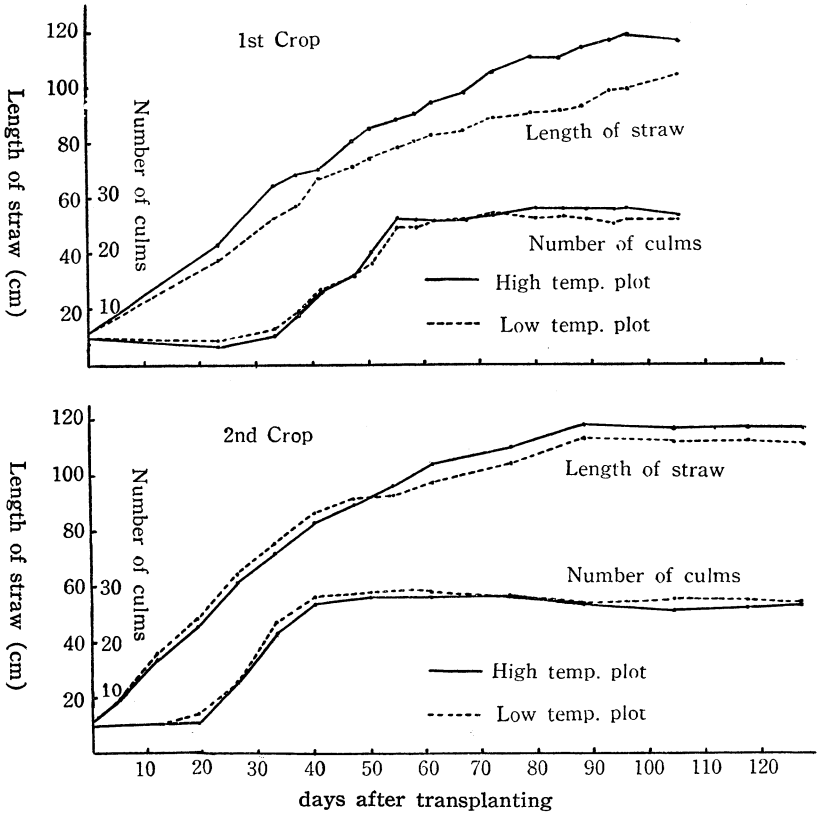

Fig 2. Growth status of rice plants at successive stage of growth

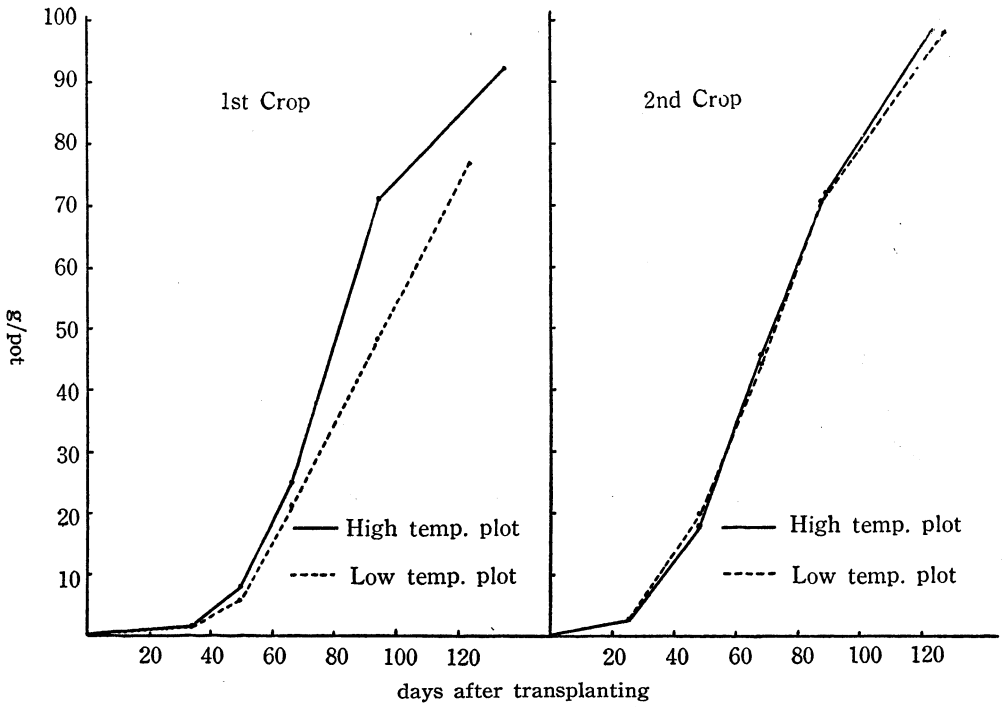

Fig 3. Weights of rice plants at successive stage of growth
(air-dry weight per pot)

Table 5. Amounts of inorganic nutrients absorbed by rice plants at successive growth stages (mg/pot)

		High temp. plot				Low temp. plot		
		N	P_2O_5	K_2O		N	P_2O_5	K_2O
1st Crop	Mar. 26 (planting)	1.0	0.7	1.3		1.0	0.7	1.3
	Apr. 28	31.1	8.3	42.4		24.7	5.8	18.5
	May 15	275.7	52.9	298.7		231.5	46.7	123.4
	June 1	699.9	170.7	778.9		671.8	169.9	286.1
	June 29	1,036.8	380.5	1,123.6		730.8	307.9	399.7
	Aug. 8 (harvesting)	1,107.0	492.2	1,380.8	July 28	775.1	385.9	613.6
2nd Crop	Aug. 13 (planting)	1.6	0.5	2.1		1.6	0.5	2.1
	Sep. 8	65.9	17.8	93.8		93.5	23.6	126.0
	Oct. 1	568.4	152.3	717.2		562.5	145.9	645.3
	Oct. 21	870.8	309.5	1,386.9		888.7	308.7	1,160.0
	Nov. 9	910.6	414.5	1,582.6		936.9	397.0	1,287.0
	Dec. 18 (harvesting)	1,059.6	499.9	1,642.1		1,137.6	449.4	1,371.7

In general, the absorption of three elements by rice plants, especially of potassium, was promoted under high temperatures. In the 1st crop, the total amounts of potassium absorbed by a plant in the high temperature plot were twice as much as that in the low temperature plot, and moreover the amounts of potassium absorbed in the 2nd crop were larger than that in the 1st crop. This fact is of interest with regard to the favourable availability of potash fertilizers in the 2nd crop season of Taiwan in

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Table 6. Distribution of inorganic nutrients in rice plants

			N		P_2O_5		K_2O	
			mg/pot	Index	mg/pot	Index	mg/pot	Index
1st Crop	High temp. plot	Grain	162.8	(15)	75.83	(15)	78.91	(6)
		Stem	111.4	(10)	119.24	(42)	178.20	(13)
		Leaf	832.8	(75)	297.18	(60)	1,123.69	(81)
		Total	1,107.0	(100)	492.25	(100)	1,380.80	(100)
	Low temp. plot	Grain	323.1	(42)	149.57	(39)	151.78	(25)
		Stem	81.6	(10)	93.91	(24)	145.34	(24)
		Leaf	370.4	(48)	142.42	(37)	316.50	(52)
		Total	775.1	(100)	385.90	(100)	613.62	(100)
2nd Crop	High temp. plot	Grain	503.02	(47)	252.23	(50)	232.83	(14)
		Stem	115.43	(11)	119.28	(24)	671.62	(41)
		Leaf	441.15	(42)	128.37	(26)	737.66	(45)
		Total	1,059.60	(100)	499.88	(100)	1,642.11	(100)
	Low temp. plot	Grain	446.03	(39)	197.04	(44)	189.71	(14)
		Stem	182.62	(16)	106.00	(23)	495.46	(36)
		Leaf	508.95	(45)	146.37	(33)	686.53	(50)
		Total	1,137.60	(100)	449.41	(100)	1,371.70	(100)

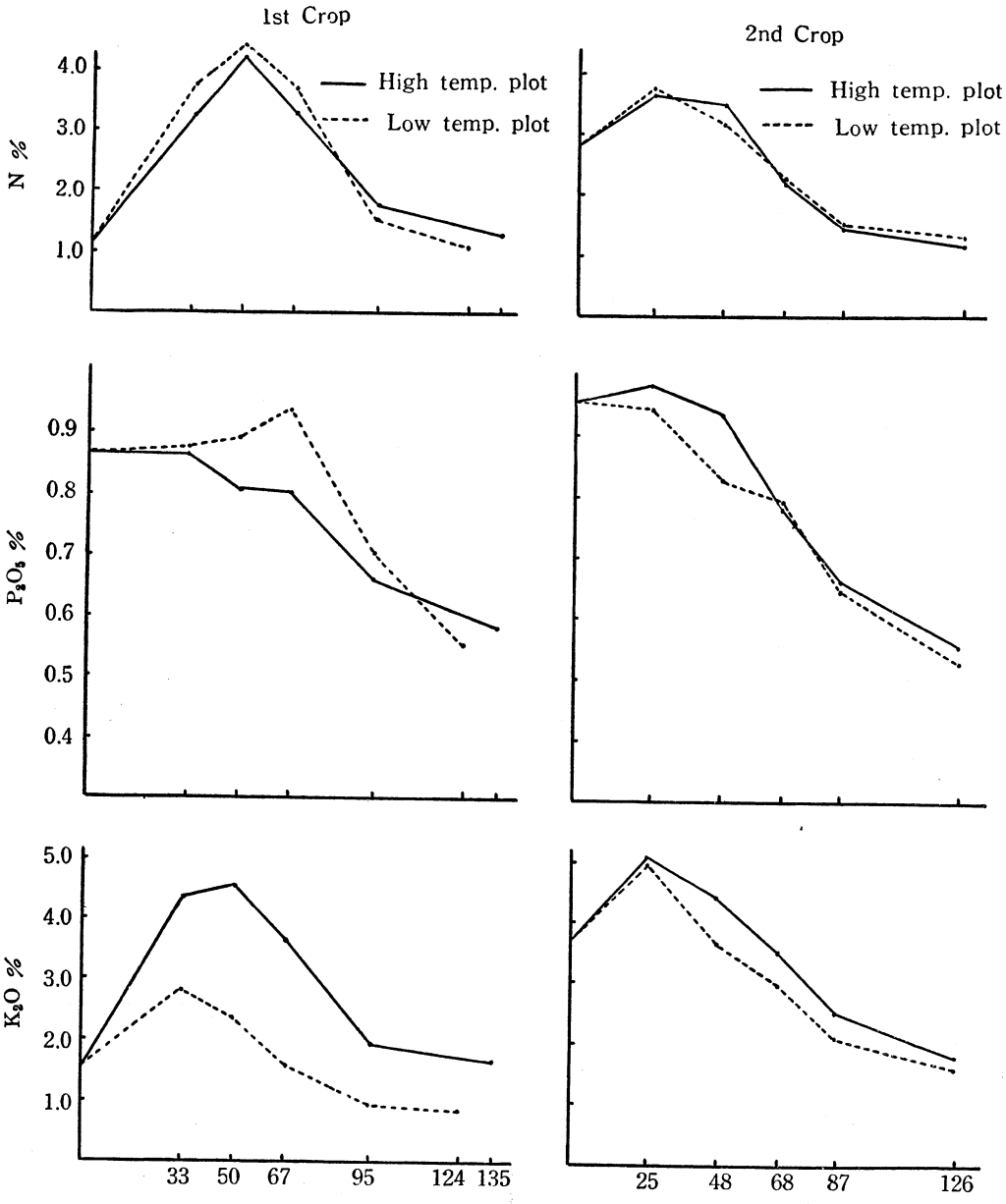

Fig 4. Change of nutrient contents in rice plants at successive growing stages

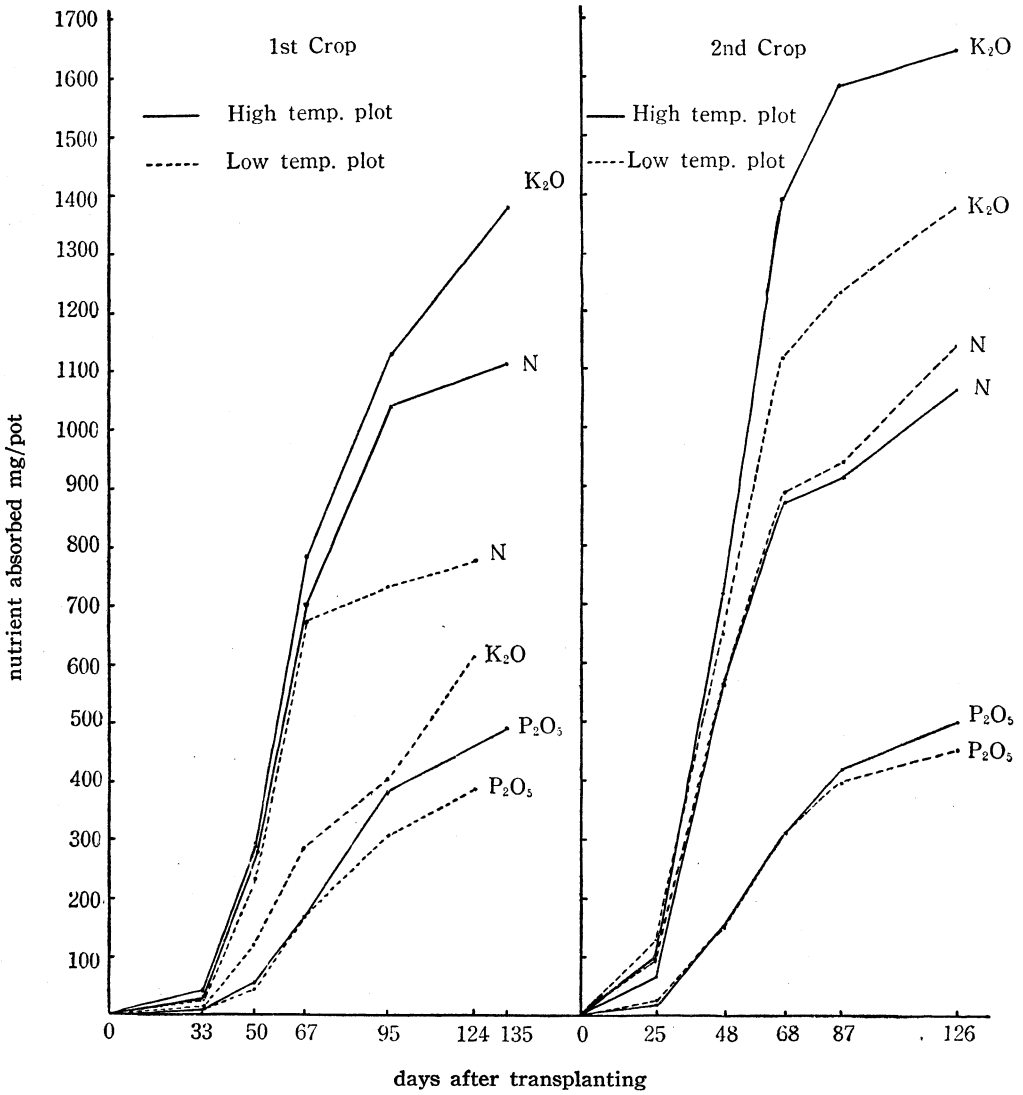

Fig 5. Amounts of nutrients absorbed by rice plants at successive growing stages

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which the temperatures are high, a larger amount of potash fertilizer is needed than in the 1st crop season.

Under this glass-house condition, the rice plants absorbed the largest amount of potassium among three elements. Nitrogen absorption came to next and phosphorus the least. Taking the amounts of total K_2O absorbed to be 100, the amounts of N and P_2O_5 absorbed were calculated as 81 and 36 respectively.

OBSERVATION

1. To get different temperatures during rice cultivation, one glass-house with windows closed and the other with windows opened were set down as high and low temperature plot respectively, so far as our present equipment can provide.

They resulted in temperature difference of 2°~3°C between them, but temperatures in both glass-houses were still higher than that of natural field conditions. Under this expermiental condition, we found that the growth status, yield and nutrient absorption by rice plants were influenced greatly by the different temperatures.

2. The length of plants both in the 1st and 2nd crops under high tenperatures was apparently larger than that under low temperatures, but number of tillers did not show an apparent difference. High temperatures also advanced heading. In the high temperature plot, heading date was 7 days earlier than that in the low temperature plot in the 1st crop and 4 days earlier in the 2nd crop. Total dry matter weights of the plants in high temperature plot was higher than that in low temperautre plot, especially in the 1st crop.

However, for the grain yields, it was observed that greater complication might existed. As shown in table 3, grain/straw ratio in high and low temperature plots was 17/100, 55/100 in the 1st crop and 67/100, 48/100 in the 2nd crop respectively. In the 1st crop, high temperatures decreased the grain yield, but in the 2nd crop, this result was just reversed. The reason was considered as follows. The high temperature plot in the 1st crop had maximum temperatures over 40°C occasionally in daytime, which had affected the pollination of flowering time. As a matter of fact, a large number of sterile grain were produced and 60% of total number of grains were sterile. Consequently, total weights of grains were reduced in the high temperature plot.

It was also found that maturity of grain was prolonged for more than 10 days by the high temperatures and the plants continue to grow vigorously even at ripening stage at the higher temperature plot. While the plants at the low temperature plot became yellowing after heading as usual ripening process. The metabolism of rice plants during the ripening period by Murayama (1957) may confirm this fact. He stated that after heading, nutrients were translocated to ear and the existence of ear will cause yellowing of leaves and weakening of root activity. If the ear is cut

away, the plant may continue to grow up and increase the dry matter weights in other organs to compensate for the loss of ear.

In the case of the 2nd crop, the grain yields in the high temperature plot were better than those in the low temperature plot. In the later growth stage of the plants in this case, since the temperature was too low for the fruiting process of rice in November and December, the high temperature plot had rather adequate condition for grain yield.

3. As shown in Fig. 4, N, P_2O_5 and K_2O contents of the plants were at maximum at about 50 days after transplantion in the 1st crop and 25 days in the 2nd crop respectively, showing that the plants absorbed nutrients more rapidly at the early stage in the 2nd crop.

K_2O contents were always higher in the high temperature plot than that in the low temperature plot. Moreover, K_2O contents in the 2nd crop were also higher as compared with the 1st crop throughout the stages. This is of considerable theoretical interest in connection with the fact that potassium is readily absorbed by rice plants under high temperatures. However, in the low temperature plot in the 1st crop, the comparatively low concentration of K_2O in comparison with that of N throughout the growth stages can not be interpreted and require further investigation. For it is generally accepted that K_2O contents is higher than N contents in rice plants.

The temperature generally did not affect the N and P_2O_5 contents significantly, but it appeared that N and P_2O_5 contents in the low temperature plot were slightly higher than that in the high temperature plot before heading in the 1st crop.

4. Amounts of three elements absorbed by rice plants had a tendency in accordance with their concentrations in the plants. High temperatures certainly promoted rice plants to absorb potassium. According to Fujiwara (1956), potassium is regarded as a regulator for plant respiration. In the case of intense respiration, plants instinctively absorb more potassium to oppress respiration actibity. The high temperature treatment or comparatively high temperature in the 2nd crop, rice plants are certainly promoted the respiratory function which in turn might increase potassium absorption.

Average amounts and indices of N, P_2O_5, K_2O absorbed by rice plants per pot in this experiment were estimated as follows; N 1,019 mg (100), P_2O_5, 457 mg (45), K_2O 1,252 mg (123). Rice plants absorbed the largest amounts of potassium and the least of phosphorus.

5. According to the distribution of three elements in rice plants at harvesting as shown in Table 6, the greater part of nutrients was hold in straw rather than grain under high temperatures in the 1st crop. While in the 2nd crop, more nutrients were translocated to grain in the high temperature plot than in the low temperature plot. It resulted from proper conditions of temperature for grain yield as discussed in preceeding paragraph.

Judging from the above results, it may be stated that the study of nutrient absorption by rice plants would take an important role in the problem of the cause of low yield of rice in tropical countries. So, it is proposed to proceed the experiment along this line.

SUMMARY

The effect of high and low tempertures on the nutrient absorption by rice plants were studied by pot experiments in the two glass-houses. One glass-house with windows-clossed and the other with windows-opened are considered as the high and low temperature plots respectively. The former had temperatures 2°~3°C higher than the latter on the average during the growing period.

The growth status, yield and nutrient absorption by rice plants under these two temperature conditions were comparatively studied. The results were obtained as following.

Table 1. Growth and yield of rice plants at harvesting

	1st crop, 1949		2nd crop, 1959	
	High temp. plot	Low temp. plot	High temp. plot	Low temp. plot
Height of plant (cm)	116.6	104.0	117.4	111.8
Number of tillers	26.6	26.2	26.4	26.8
Total yield (g/pot)	92.2	76.9	101.75	98.1
Grain (g/pot)	13.7	27.2	40.80	31.8
Straw (g/pot)	78.5	49.7	60.95	66.3
Grain/Straw ratio	17/100	55/100	67/100	48/100

The high temperature apparently promoted the elongation of plants, similarly in the 1st and 2nd crops, but had little effect on number of tillers. The dry matter weights of the plants in the high temperature plot were always larger than those in the low temperature plot. In the 1st crop, high temperatures decreassed the grain yield, but in the 2nd crop, this result was just reversed. The details on yields were discussed in foregoing.

The N, P and K contents of the plants were increased gradually after transplanting. The plants reached the highest contents of N, P and K at about 50 days after transplanting in the 1st crop and 25 days in the 2nd crop, then the nutrient contents made a slow dropping till harvesting time. It was found K contents of the plants in the high temperature plot, especially in the 1st crop, were evidently higher than that in the low temperature plot.

In general, the absorption of three elements by rice plants, especially for potassium, was greatly promoted under high temperatures. In the 1st crop, the total amounts of potassium absorbed by the plants in the high temperature plot were twice as much as that in the low temperature plot. Moreover, potassium absorption was larger in

Table 2. Amounts of inorganic nutrients absorbed by rice plants (mg/pot)

	High temp. plot			Low temp. plot		
	N	P_2O_5	K_2O	N	P_2O_2	K_2O
1st crop	1,107	492.2	1,380.8	775.1	385.9	613.6
2nd crop	1,059.6	499.8	1,652.1	1,137.6	449.4	1,371.7

the 2nd crop as compared with that in the 1st crop. This fact is of interest with regard to the favourable availability of potasic fertilizers in the 2nd crop season in Taiwan in which the temperatures are high, a large amount of potassic feritizer is needed than in the 1st crop season.

Average amounts and indices of N, P_2O_5, K_2O absorbed by rice plants per pot in this experiment were estimated as follows; N 1,019 mg (100), P_2O_5 457 mg (45), K_2O 1,252 mg (123). Rice plants absorbed the largest amounts of potassium and the least of phosphorus.

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臺灣水稻之養分吸收之研究（第一報）

溫度對養分吸收之影響

邱再發　連　深　徐水泉*

摘　要

本試驗目的在探討溫度對水稻養分吸收之影響。試驗於兩玻璃室內同時進行，其一係玻璃窗全部開啓，另一則全部關閉以爲比較上之高低溫區。其平均溫度差異如表 1.

表 1. 兩玻璃室平均溫度

	第一期作 1959	第二期作 1959
高溫區	30.9°C	29.8°C
低溫區	27.9°C	27.0°C
差異	3.0°C	2.8°C

在此種溫度處理下舉行水稻盆栽，調查比較各階段之生育情形，養分吸收狀態和收量，結果如下。

（1） 水稻收穫時之生育狀態及穀藁收量如表 2.

表 2. 收穫調查結果

	第一期作 1959		第二期作 1959	
	高溫區	低溫區	高溫區	低溫區
株高 (cm)	116.6	104.0	117.4	111.8
分蘖數	26.6	26.2	26.4	26.8
總收量 (g/盆)	92.2	76.9	101.75	98.10
穀 (g/盆)	13.7	27.2	40.80	31.80
藁 (g/盆)	78.5	49.7	60.95	66.30
穀/藁比	17/100	55/100	67/100	48/100

高溫處理無論在第一期或第二期作均促進水稻株高，惟對分蘖則影響很小。乾物總收量亦以高溫區大於低溫區。至於穀收量則第一期作之高溫處理顯然因對水稻之生殖生長具有惡劣影響，而致減低很多，但在第二期作高溫之效果却反而良好。其詳細如本文。

（2） 就水稻三要素含有率之推移狀態觀之，插秧後各要素之濃度均有增高，第一期作約於 50 天，第二期作約爲 25 天左右達到最高後開始逐漸減低，直至收穫期。三要素含有率之溫度處理間差異以鉀較爲明顯，即高溫區之鉀素含有率顯然高於低溫區（尤其在第一期作）。

概言之，溫度之提高顯然可以增加養分吸收量，惟此種傾向以鉀素爲最。如表 3. 第一期作高溫區之鉀素吸收量高於低溫區竟達兩倍以上。第二期之鉀素吸收量較之第一期作亦顯然提高。此

* 臺灣省農業試驗所

種現象和臺灣第二期作之高溫下鉀肥肥效較第一期作明顯之事實對照，甚值進一步之探討。

表 3. 水稻無機養分吸收量 (mg/pot)

	高溫區			低溫區		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O
第一期作	1,107.0	492.2	1,380.8	775.1	385.9	613.6
第二期作	1,059.6	499.8	1,642.1	1,137.6	449.4	1,371.7

本試驗水稻之三要素吸收量及其指數，平均每盆爲 N 1,019 mg (100), P_2O_5 457 mg (45) K_2O 1,252 mg (12.3) 可見水稻之養分吸收以鉀素最大磷素最小。